THE GREAT WIND OF APRIL 11–12, 1934, ON MOUNT WASHINGTON, N.H., AND ITS MEASUREMENT

PART I

WINDS OF SUPERHURRICANE FORCE, AND A HEATED ANEMOMETER FOR THEIR MEASUREMENT DURING ICE-FORMING CONDITIONS [1]

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[Mount Washington, N.H. (post office, Gorham, N.H.), July 1934]

Early methods and results.—While this article discusses chiefly the extremely high winds which have long been known to occur on Mount Washington, N.H., that portion of it which describes the sturdy heated anemometer recently built for this station, and which automatically frees itself from rime and ice during the most extreme winter conditions, is of more general interest since this device is suitable for all localities subject to such conditions.

The character of the winds prevailing on the stormy summit of Mount Washington was well determined by the observations beginning June 5, 1871, and maintained throughout the years for more than 17 years by the United States Signal Corps.

Extremely high average wind movements were recorded the year around, and velocities in excess of 100 miles per hour were frequently experienced, particularly during the winter months. A parallel with free-air conditions could not be satisfactorily established, and explanations of these unusually high surface-wind velocities were hypothetical and qualitative.

The chief difficulties experienced by the United States Signal Service in connection with wind measurement on Mount Washington were:

1. Ordinary cup anemometers could not stand the terrific impact of superhurricane winds.

2. The presence of rime-forming fog on the summit 9 months of the year, and during some of the winter months more than 50 percent of the time.

Rime depositing on the rotor would slow it down gradually to a standstill, and generally bend the cup arms.

The first problem was partly solved by building a rugged, heavily-braced cup anemometer of standard dimensions. Doubtless due to the complete absence in those early days of wind tunnels or other means of adequately testing such instruments, very little is said on the performance of this instrument in the station records or the reports of the Chief Signal Officer. In fact, its run was assumed to be the same as that of the lighter cup wheels, namely, 500 rotations to the indicated mile.

One of these instruments was subjected to a single test run in 1922 by Mr. S. P. Fergusson. This test, extended to a wind speed of 136 miles per hour, showed that from 20 miles per hour upward the light cup wheels ran from 8 to 10 percent faster than the heavy pattern. This means that all such high velocities recorded in the past at Mount Washington are more nearly true velocities than heretofore supposed.

The observatory journal, however, as late as 1886, reports that anemometer cups were still being blown off and records lost.

The solution of the problem of rime forming on the cups was attempted at the expense of considerable effort. The observers were instructed to change the anemometers frequently during periods of rime-formation—an operation often performed with great difficulty and hardship. In October 1887, the journal reads: "Anemometer being froze up was removed from the roof for the winter." In March 1881: "During March 1881, frost formation prevented wind velocity readings on 27 days."

The new method.—It was obvious at the time of reoccupancy of the summit of Mount Washington for meteorological observations, October 1932, that a new method should be tried in order to obtain a continuous record of wind movement. The conventional type of cup anemometer was replaced by an instrument having a specially designed cup-wheel rotor equipped with a stationary electric stove unit, connected with the 110-volt D.C. gasoline-electric unit of the Observatory. This new instrument, installed on the observatory building, 8 feet above the roof-ridge, recorded every mile of wind on a chronograph the charts of which were changed weekly. Heat was applied during the long and frequent periods of rime and ice-deposition. A maximum velocity of 164 mi./hr. was recorded April 5, 1933.

Early experience proved the inadequacy of this design and the need of improvements. A new anemometer, described in the next part, designed with the cooperation of those who were acquainted with the deficiencies of the first instrument, was built early in 1933 by the Mann Instrument Co., 23 Church Street, Cambridge, Mass., with the aid of the Permanent Science Fund of the American Academy of Arts and Sciences.

The velocity-characteristic of the new instrument is far from ideal, and its sensitiveness at velocities below 10 miles per hour is practically zero. Its chief purpose, however, is to record continuously, with the accuracy of modern methods of standardization, rimeforming winds of superhurricane force. Low wind velocities, which in the winter months give a negligible fraction of the total wind movement, are measured by a cup anemometer exposed on a structure 30 feet above the geographical summit.

The new heated anemometer (fig. 6), securely installed 10 feet above the roof ridge, has proved to be entirely satisfactory, the only trouble experienced during the whole winter having been a damaged ball bearing, and a burnout of the auxilliary (air-gap) heater. In both instances the spare no. 1 anemometer secured the record while the no. 2 instrument was being repaired.

A few breaks in the continuity of the records last winter (1933–34) were due to improper operation of the gasoline-electric unit at very low temperatures. In most cases, however, it was possible to interpolate average wind velocities with a fair degree of accuracy.

The calibration of the no. 2 anemometer and the extrapolation of corrections are fully discussed in part III, page 191.

The anemometer functioned perfectly in foggy weather, at a temperature of 46.5° F. below zero in a wind that averaged 100 mi./hr. and increased to 120 mi./hr. as the air temperature rose to 42° F. below.

THE STORM OF APRIL 11–12,1934

The low pressure which caused the greatest 24-hour wind movement ever recorded on Mount Washington,

[1] Paper read at the meeting of the American Meteorological Society, Washington, D.C., April 1934.

N.H., and the highest wind velocity ever officially recorded anywhere in the world by accurately-tested instruments, was preceded there by a period of 48 hours of fair weather with normal pressure, temperature, and other meteorological elements. On the afternoon of April 10 a singular period of near calm was experienced. But the pressure fell slowly from the afternoon of April 11 until 6 a.m., April 12, and then more rapidly (fig. 1), under the influence of the low-pressure area centering over the eastern part of the Great Lakes region.

On the morning of April 11, there was an emissary sky with Cirrostratus, Cirrus densus, Cirrus filosus, and some Altocumulus lenticularis, moving from the west. At 8 a.m. low Stratocumulus was seen rapidly advancing over an extended front from the east. At 11 a.m., while the upper sky was covered with eight-tenths Cirrostratus filosus, Cirrus filosus, and Cirrus densus, the low Stratocumulus from the east began arching over the summit of the mountain. The southeast wind had reached a velocity of 80 miles per hour, [2] and was steadily increasing. The temperature held about 22° F. without any appreciable change. Rough frost began forming soon after the summit became enveloped by clouds.

The afternoon of April 11 was characterized by a heavy southeast wind of moderate gustiness, reaching a maximum of 136 miles per hour. During the following night the hourly wind movement was never less than 107 miles (fig. 1) and rough frost formed rapidly.

The morning of April 12 was characterized by a rapidly increasing southeast wind of appreciable gustiness, steadily falling pressure, slightly rising temperature from a minimum of 15° F., reached at 2 a. m., and a light fall of granular snow. Rough frost accumulated heavily throughout the day, with a fairly well defined feathery appearance, icy structure, high water content, and producing a characteristic deep-blue light reflection.

At the time of, and just after, the great storm the records were read and corrections worked out somewhat hurriedly, but nevertheless as carefully as possible. Moreover, as the maximum test speed was about 143 mi./hr. the corrections of the superhurricane wind gusts of over 200 mi./hr. involved somewhat uncertain extrapolations of the calibration curve. However, the outstanding features of the record are presented briefly below.

In the course of preparation of this paper, and in order to establish all the facts of such important records, arrangements were made with the cooperation of the Chief of the Weather Bureau and the Director of the Bureau of Standards to subject the anemometer to one or more new tests. The attention of the reader is invited to Dr. C. F. Marvin's discussion of all the tests and his refined analysis of the record and extrapolation of corrections beginning page 191.

At noon, April 12, the hourly wind movement had risen to 155 miles with gusts reaching a velocity well above 200 mi./hr. From 12 noon to 1 p.m., while other conditions were comparatively unchanged, the wind attained its extreme force. Between 12:25 p.m. and 12:30 p.m., a 5 minute average wind velocity of 188 mi./hr. was recorded on the Weather Bureau type multiple register (fig. 2). Gusts were frequently timed by two observers, with stop-watch and Nardin chronometer, and the values obtained corrected by means of the extrapolated calibration curve of the United States Bureau of Standards, (fig. 9–A).

[2] Unless otherwise indicated all velocities are given in true miles per hour.

While frequent values of 225 mi./hr., including two-thirds mile at this speed, were obtained, several gusts of 229 mi./hr. were timed, and at 1:21 p.m. the extreme value of 231 mi./hr. for a succession of 3 one-tenth mile contacts was timed twice. This is the highest natural wind velocity ever officially recorded by means of an anemometer on Mount Washington or anywhere else.

The hourly movement between 12 noon and 1 p.m. reached a peak of 173 miles.

The barograph, 6,284 feet above sea level, showed vigorous oscillations of two-tenths inch maximum amplitude. The lowest pressure of 22.82 inches was recorded at 12:45 p.m.

In the afternoon the force of the wind decreased rapidly, while the snowfall increased in intensity. The pressure rose rapidly between 4 p.m. and 6 p.m. and more gradually thereafter. At 8 p.m. the total snowfall for the previous 24 hours was 10 inches and had a water equivalent of 3.78 inches. The huge accumulation of rough frost had reached a maximum thickness of 3 feet on the most exposed objects.

The maximum 24-hour wind movement was obtained between 4 p.m. April 11, and 4 p.m. April 12, with a total of 3,095 miles and an average of 129 mi./hr.

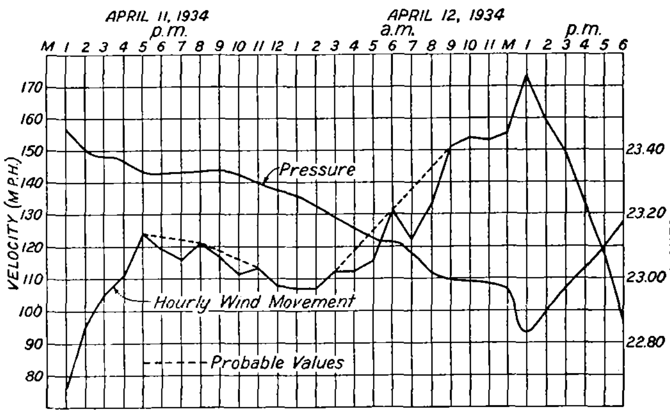

FIGURE 1.—Air pressure and average hourly wind travel Mount Washington, N.H., elevation, 6,284 feet, April 11 to 12, 1934.

Although the anemometer was well exposed to the southeast wind, the rapid accumulation of rough frost around the lower portion of the 10-foot staff seemed to have had the tendency to break somewhat the force of the wind, since the wind-movement curve (fig. 1) shows decided increases of velocity following each cleaning of the anemometer post immediately below the instrument. The figures obtained, therefore, should be considered as somewhat conservative.

Every mile of wind was recorded by the special electrically heated anemometer.

No serious difficulty was experienced by the observers in attending to their outdoor duties necessary under the extreme conditions. The much discussed question whether a man can stand up under the heavy pressure of such a strong wind remains still a matter of speculation. Experienced men seem to react to the impact of the wind with various adjustments such as bending themselves toward the wind, lowering the body by spreading the legs, and exposing the side of the body to the wind. These various counteractions, difficult to evaluate in terms of force, and variable with different individuals, together with the fact that the wind pressure is less by one-fifth part or more at the summit than at sea level make it possible for persons

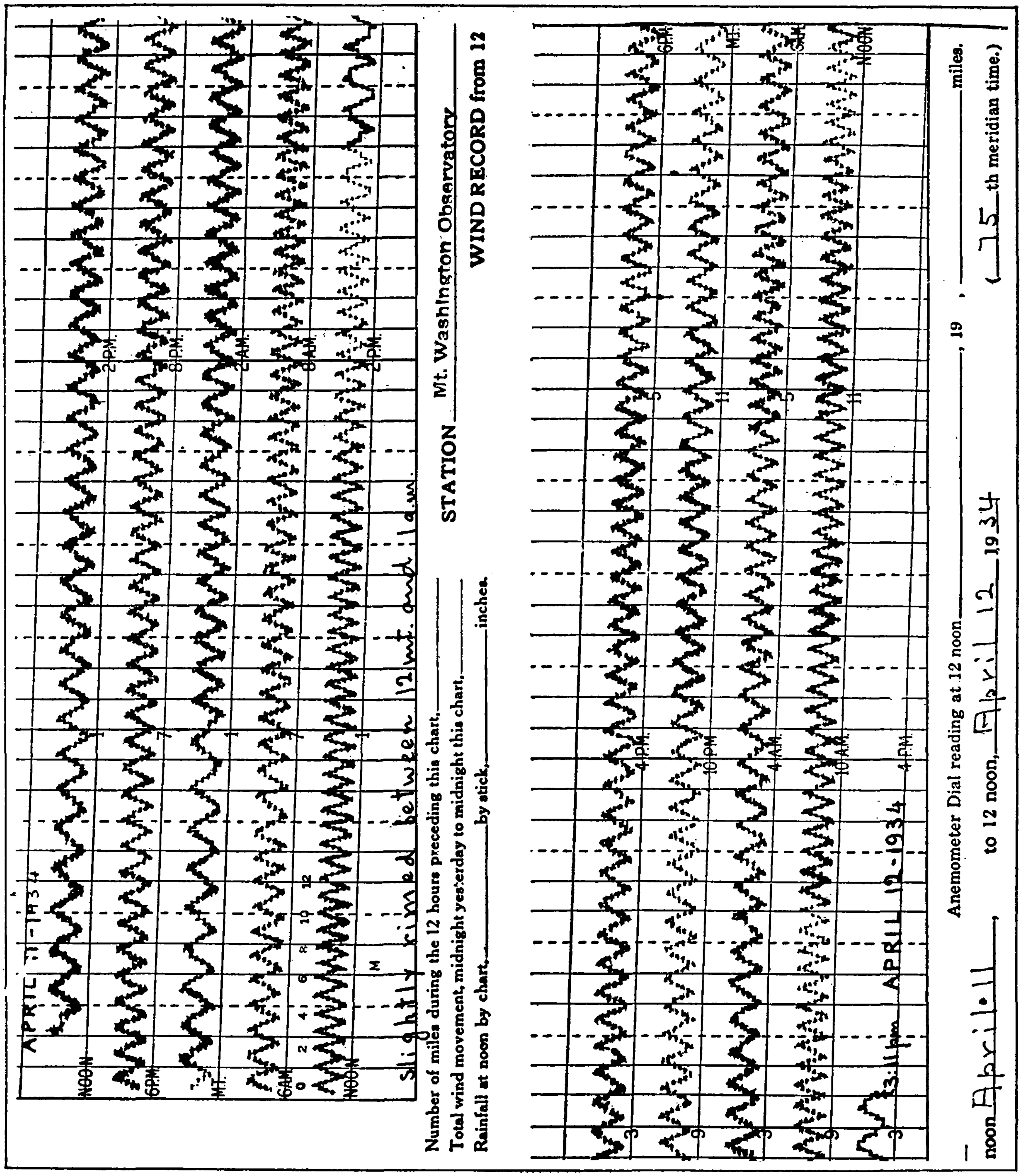

FIGURE 2.—Full-scale copy of record of wind velocity from 12:10 p.m. April 11, to 1:30 p.m., April 12. Wind direction generally from the southeast.

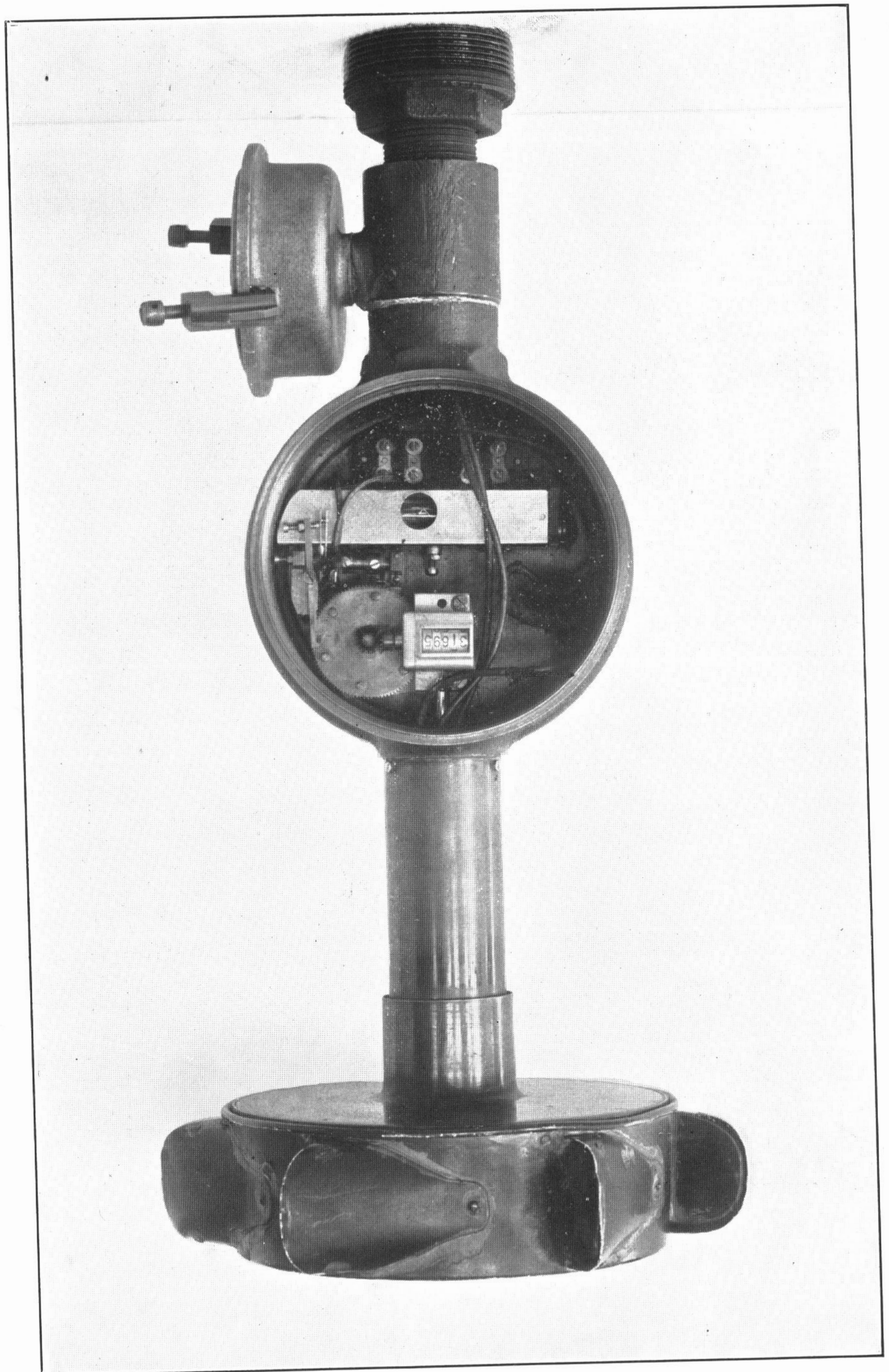

FIGURE 3.—Perfected heated anemometer no. 2, showing dial mechanisms.

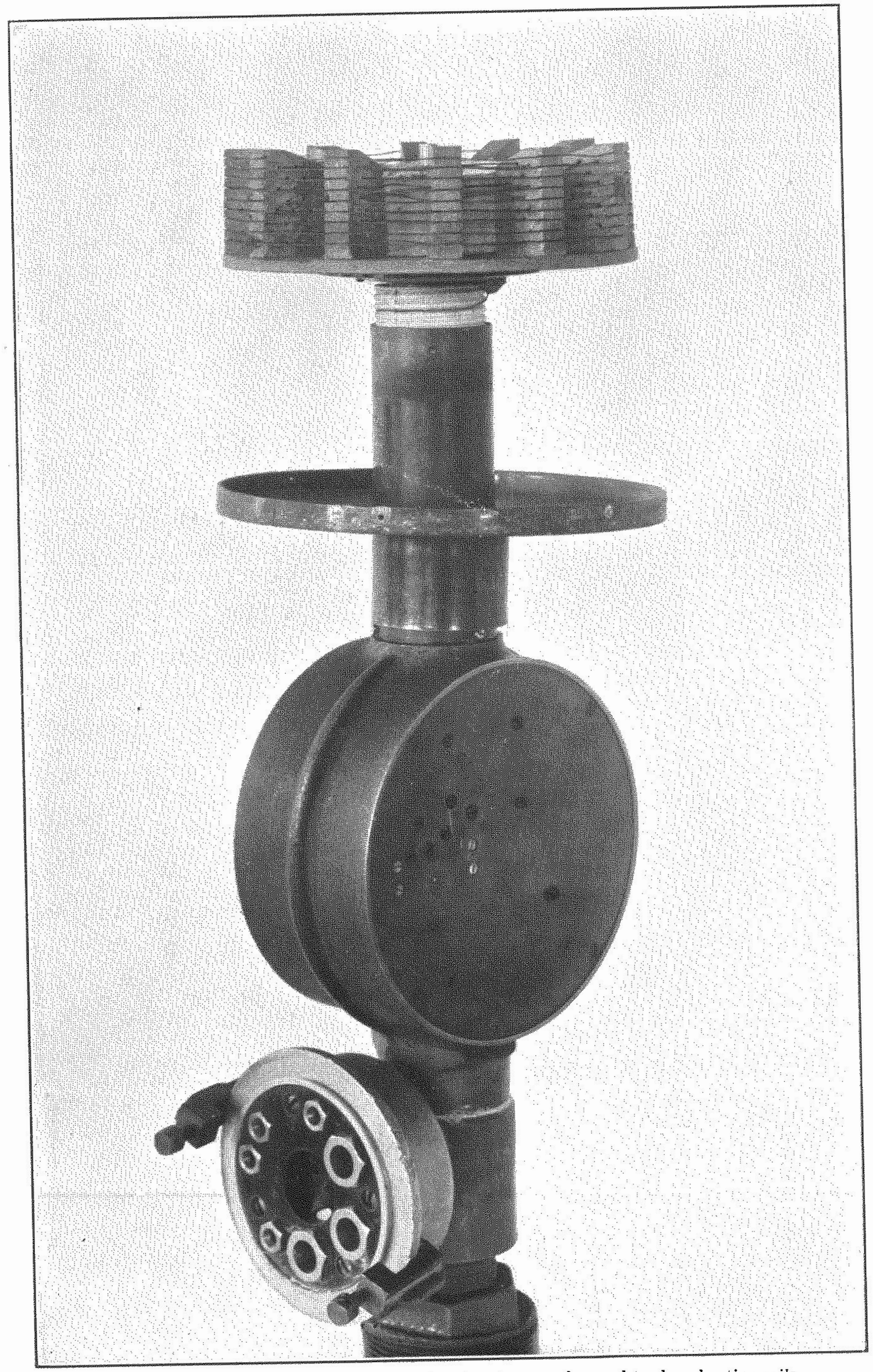

FIGURE 4.—Anemometer with rotor removed and undercover lowered to show heating coils.

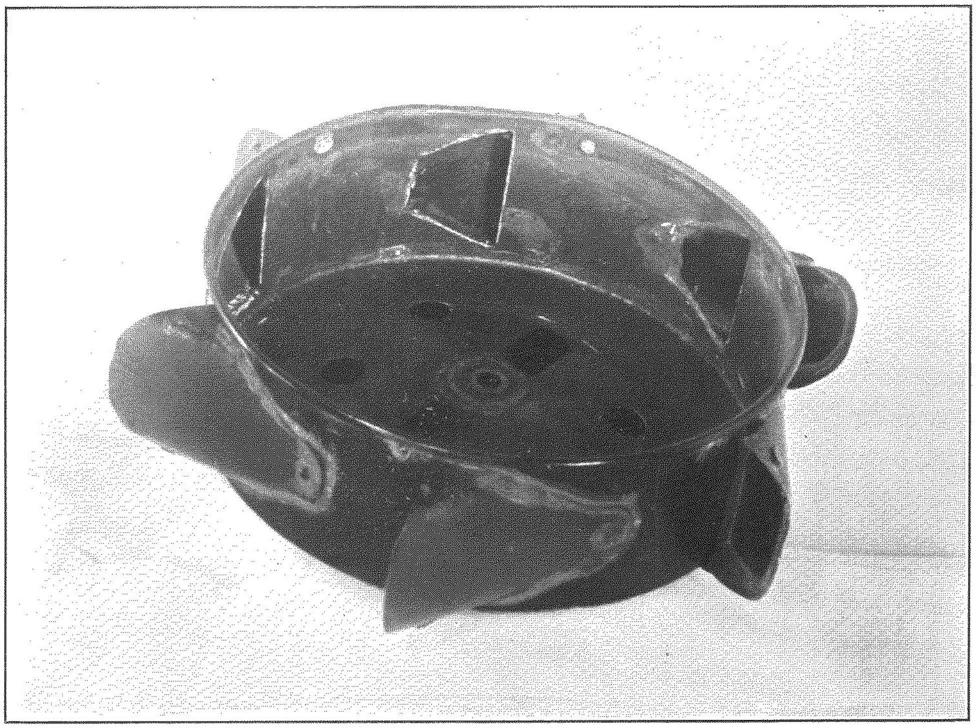

FIGURE 5.—Rotor inverted to show stiffening web at top and lateral heating vents into cups.

FIGURE 6.—Mount Washington Observatory with anemometer in place.

to withstand the force of extremely strong winds with tolerable difficulties. Besides the velocity is much less near a rough rocky surface than in the free air where the anemometer is exposed.

Only slight damage occurred, chiefly to the exposed instruments. A structure supporting a special wind vane, situated at the end of the trestle, partly collapsed and badly smashed a snow gauge. Another wind vane on the trestle was slightly damaged, and the wind vane on the summit tank developed trouble. The observatory building shook considerably under the severe impact, but obviously the heavy covering of rough frost on the exposed east side, and on the roof, must have increased greatly the rigidity of the structure. The delicate pyrheliometer bulb did not suffer the slightest damage, and was found to be covered by a singularly small amount of frost. The telephone line from the summit to the base station was also undamaged.

From 12:35 to 1 p.m. April 12, the one-thirtieth mile contact clicks from the anemometer were broadcast from the observatory's ultra-short (5 m) wave transmitter and were received at the Blue Hill Observatory in Milton, Mass., 142 miles south, by Director C. F. Brooks, who timed the contacts by intervals of 5 seconds. Five samplings of one or two minutes each from 12:37 to 12:55 p.m. showed "true" velocities by 5-second intervals ranging from 108 to 216 mi./hr. The fastest 40 contacts, representing a true mile, came in only 17 seconds, or at a rate of 3½ miles a minute (210 mi./hr.). The mean velocities by whole minutes ranged from 148 to 192 mi./hr., and for the 5½ minutes as a unit, a random sampling of this windy hour, 172 mi./hr.

PART II

THE MOUNT WASHINGTON, N.H., HEATED ANEMOMETER

By D. W. MANN

[Mann Instrument Co., 23 Church Street, Cambridge, Mass.]

As briefly mentioned by Dr. C. F. Brooks in the Engineering News Record of May 10, 1934, an experimental heated anemometer which prevented ice deposits was shown him by Dr. Sverre Pettersson, of the Norwegian Weather Service at Bergen, Norway. Using Dr. Brooks' recollection of this instrument as a basis, and working in cooperation chiefly with Mr. S. P. Fergusson and others at the Blue Hill Observatory at Milton, Mass., the writer first constructed an experimental model which, after a preliminary test in the wind tunnel at the Guggenheim Aeronautical Laboratory of the Massachusetts Institute of Technology was put in use for some months on Mount Washington. Later, in October 1933, the anemometer was given further tests at high-wind speeds at the United States Bureau of Standards. This first model was not entirely satisfactory, but the experience gained indicated clearly where improvements were needed in the design to meet the severe conditions to be expected on Mount Washington.

An anemometer was then designed and built embodying the improvements indicated, and with a few minor changes the instrument has since given satisfactory service.

Figure 3 illustrates the anemometer with the front glass removed to show as clearly as possible the electrical mechanism. The main body consists of a bronze casting with a projecting tube above and a base below. This base is fitted with pipe threads to facilitate mounting the instrument on its roof support.

To the base is permanently attached one-half of an electrical junction box, with which both heating and signal circuits are connected. A vertical shaft carrying the rotor passes through the vertical tubular section of the main body and connects the rotor with reduction gearing located in the central section of the case.

Some of the more important features of the internal mechanism are shown in figure 7. Figure 5 is a photograph of the rotor removed from the instrument and inverted to permit inspection of its interior. The rotor made from hard drawn sheet copper spun into a flat pan 6 inches in diameter and 2 inches deep, has a rolled edge to add to its rigidity. The six fins projecting from its outer edge are, practically, shallow cups. The periphery of the rotor is perforated at each cup to permit passage of heated air into the interior of the cup. The diameter of the rotor over the tips of the opposite cups is 8.25 inches and its weight complete without axis is 22 ounces.

To prevent vibration of the rotor an internal bracing web made from spun copper is fastened rigidly to the rotor at its outer edge, and to a brass hub at the center. This hub permits attachment of the rotor to the main shaft by means of a key engaging a keyway in the latter. A screw into the shaft through the top of the rotor holds it firmly in place. This screw does not project above the top of the rotor, because early experiments showed clearly that no projection could be permitted, frost feathers having formed on even a very short thumb screw.

To enclose the heating coils the lower side of the rotor is provided with a spun copper unit having a tubular center, shown in figure 4. In this figure the rotor is removed and the lower part dropped to show the heating coils. To provide for the complete defrosting of the rotor, the air gap between its tubular part and the column is made relatively small, and auxiliary heat is provided at this point. However, this gap is of necessity large enough to prevent the rotor touching the stationary column even under conditions of maximum vibration.

The heating coils consist of Nichrome wires threaded through holes in a series of transite pillars supported by a flat transite disc secured to the main column. Below this transite assembly is the auxiliary heater which consists of a threaded Isolantite tube, upon which is wound the heating coil for defrosting the air gap below the rotor.

The electrical circuits are so connected that the current used in the rotor heating units passes through the auxiliary gap heater and the amount of heat delivered at the gap is somewhat proportional to that used above. Two windings are provided inside the rotor and leads carried through the junction box so either winding may be used alone, or both together as the maximum current required is about 700 watts. To facilitate warming the cups, and in order to prevent overheating of the top bearing, the heating units are concentrated as near as possible to the outer edge of the rotor, and a tube of heat-insulating material is provided to retard the passage of heat from the heater to the bearing in question.

Figure 4 also shows the plug sockets in the junction box; four small ones for the recording circuits, and three larger ones for the heating circuits. Separate leads are used for all electrical circuits, these being entirely insu-